Microcredit from Delaying Bill Payments

William Violette*

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Abstract

Delaying bill payments to public utilities may provide an important strategy for households with volatile incomes to smooth their consumption. At the same time, delaying bill payments contributes to utilities' costs, which are often passed on to households through prices. Using billing records from a large water utility in Manila, this paper builds a consumption and savings model to estimate household demand for both water and credit. Simulations find that a popular proposal to ensure upfront payments — prepaid metering — recoups less revenue than needed to compensate households for their loss of consumption smoothing. Alternatively, households would be willing to pay up to an 18% premium on their water bill to enact a revenue-neutral policy that reduces the utility's enforcement of delinquent bills by 50%.

Keywords: credit constraints; consumption smoothing; water utilities.
JEL Codes: O13; E21; L95.

*Federal Trade Commission, Washington, DC. E-mail: william.j.violette@gmail.com Any opinions and conclusions expressed herein are those of the author and do not necessarily represent the views of the Federal Trade Commission or its Commissioners.

1. Introduction

Households face a dynamic problem of how to smooth their consumption over time, especially in low-income settings where households have little access to formal credit and risky income streams (Morduch [1995]). Households often resort to costly money lenders or informal arrangements with family members (Banerjee and Duflo [2007]).

Firms may provide an additional channel for consumption smoothing by allowing households to delay their payments for goods and services. Public utilities often tolerate high levels of delinquent bills each month. Regulations also prevent utilities from disconnecting some households for nonpayment especially in extreme circumstances. For example, utilities around the world have delayed or suspended disconnections in response to the COVID-19 epidemic.[1] Delaying bill payments may provide an economically important source of credit for households since public utilities cover broad populations and take up approximately 5% of household incomes in developing countries.[2]

Delaying payments also imposes costs on firms. Public utilities spend resources visiting and disconnecting delinquent households for nonpayment. These costs can raise prices for all households since public utility prices are often regulated to cover production costs (Hoque and Wichelns [2013]).[3] As a result, policymakers have recently pushed for new prepaid metering technologies, which require upfront payments before releasing any services. Recent research confirms that prepaid meters substantially increase utility revenues (Jack and Smith [2016]). Prepaid meters for electricity already compose over 28% of residential meters in Sub-Saharan Africa and are predicted to grow to 53% by 2024 (Northeast Group [2014]).[4] Despite this growth, existing research has yet to consider how these technologies may impact household welfare by reducing consumption smoothing.

This paper incorporates delayed bill payments into household consumption and savings decisions in order to evaluate the welfare effects of counterfactual payment policies such as prepaid metering. This paper studies a large piped water utility in

[1] Buford and Campbell [2020] list municipalities in the US who have and have not suspended disconnections in response to COVID-19. Domingo [2020] reports how utility disconnections in Manila, Philippines have been delayed by 30 days in response to the COVID-19 epidemic.

[2] Komives et al. [2006] find that households spend 1-2% of their incomes on water and 4% on electricity.

[3] Laffont [2005] discusses economic reasons for revenue-neutral pricing, which is common in both developed and developing country settings.

[4] By planning to install over 300,000 prepaid meters, the Botswana Water Utilities Corporation provides an example of the growing use of this technology in the water sector as documented by Heymans et al. [2014].

Manila, Philippines where detailed administrative data record household consumption, bill payments, and disconnections for nonpayment. In Manila, unpaid water bills average 5.5% of household income, exceeding most other sources of short-term credit.[5] Descriptive evidence suggests that households time their bill payments to smooth their consumption when they face sudden income changes. Out of each 100 PhP increase in income, households spend around 1 PhP on their unpaid water bills without changing their water consumption.[6]

This paper builds a dynamic model to capture household consumption smoothing patterns. In this model, households with risky incomes can borrow from a costly asset as well as from delayed payments to the water utility. While delayed bills charge no interest, households face some probability each month of receiving a delinquency warning where they must either pay their bills immediately or disconnect and use an alternative water source. The model estimates the warning probability using households' observed unpaid bills and estimates household preferences using observed water consumption. The estimated model matches descriptive evidence that households make large, infrequent payments and leave large unpaid balances when they disconnect permanently.

The estimated model allows for evaluating the welfare effects of introducing prepaid meters. Prepaid meters are paired with a price reduction to ensure that the utility's net revenues remain equal to zero. This price reduction reflects cost savings because with prepaid meters, the utility no longer needs to conduct delinquency warnings and households no longer leave unpaid bills when they disconnect permanently. Simulations indicate that this price reduction is not enough to compensate households for their loss of consumption smoothing. By removing access to delayed bill payments, prepaid meters steeply lower total household borrowing.

The counterfactual exercises also consider a revenue-neutral policy that halves the utility's enforcement of delinquent bills. In particular, this policy lowers the probability that households receive delinquency warnings by 50%, which could be easily implemented by the utility. This policy almost triples the average amount of unpaid bills, indicating substantially more consumption smoothing. Despite larger unpaid bills, this policy actually results in a small price reduction because of lower enforcement costs and because of greater revenue as households substitute toward piped wa-

[5]On average, short-term loans, which are mainly from moneylenders and microcredit agencies, only equal about 2.5% of household income according to the 2014 Consumer Finance Survey.

[6]"PhP" refers to Philippine Pesos where 45 PhP = 1 USD.

ter consumption to increase their borrowing with unpaid bills.[7] This result suggests that less enforcement would more than pay for itself. Overall, this policy is predicted to improve social welfare by 117 PhP (or 2.6 USD) per household each month. Given 2.4 million piped water using households in Metro Manila, this estimate implies welfare gains up to 75 million USD each year.

This paper contributes to three main strands of economic literature. First, this paper brings payment and billing policy questions into a growing literature on optimal policy for utilities in developing countries (McRae [2015]; Szabó [2015]; Jack and Smith [2016]; Jack and Smith [2015]; Szabó and Ujhelyi [2015]). Building on previous static models, this paper also provides a framework for considering how dynamic incentives affect household demand for public utilities. Second, this paper draws on a large body of research analyzing household credit constraints, particularly through microfinance interventions (Morduch [1999]; Morduch [1995]; Cull et al. [2009]; Dupas and Robinson [2013b]; Jack et al. [2016]). Karlan and Zinman [2009] and Giné and Karlan [2014] specifically focus on microfinance in the Philippines. Third, Deaton [1991] provides the foundational model of dynamic decision-making that serves as the starting point for the model in this paper, and the estimation of this model adapts methods developed by Gourinchas and Parker [2002] and Laibson et al. [2007].

This paper proceeds with Section 2 describing the water billing data from Manila. Billing practices, disconnection policies, and institutional details are discussed in Section 3 alongside descriptive evidence. Section 4 develops a model of household consumption and savings decisions while Section 5 discusses the estimation and results. Counterfactual exercises and welfare impacts are provided in Section 6. Section 7 concludes.

2. Data

Measuring credit through delayed water bill payments requires information on water consumption and bill payments at the household-level as well as features of the credit environment in Manila.

Water consumption and bill payments come from water utility records collected as part of a research partnership with one of the two regulated utilities in Metro Manila, Philippines where each utility is responsible for serving their assigned geographic half of Metro Manila. This utility provided access to monthly billing records for each con-

[7] For example in months where households are especially credit constrained, they may choose to wash clothes at home instead of at a laundromat or drink water instead of other beverages.

nection as well as detailed information covering the regulatory structure and costs of production. Monthly billing records include meter readings, billing amount, outstanding balances, and payments spanning January, 2008 to May, 2015. Over this period, the total number of connections increased from 900,000 to 1,500,000 as the water utility expanded service access. Water connections are split into four categories: residential (90%), semi-business (4%), commercial (5%), and industrial (1%). To focus on household consumption decisions, only residential connections are included in the analysis.

To examine household demographics, billing data are merged at the connection-level to a water connection survey conducted independently to monitor the quality of the utility's service. The survey randomly interviewed households with water connections covering 15,000 households in 2008, 24,000 households in 2010, and 23,000 households in 2012. Since the survey followed a similar sampling design across rounds, 13% of households were interviewed in two waves and 1.4% of households were interviewed in three waves while remaining households were interviewed in only one of the waves. To focus on household decisions, the analysis includes only connections that are identified in this survey as serving a single household (31% of all connections).[8] The connection survey includes demographics for the households that own their water connections. Table 7 in Appendix 8.1 includes more details on how the final sample is constructed for the analysis.

A household panel survey from Pasay City provides information on household income dynamics in Manila. Pasay City is a centrally located sub-municipality of Metro Manila accounting for 3.2% of the population of Metro Manila as of 2015 and is roughly representative of households living in the utility's service area. The panel survey covers over 60% of the population of Pasay City and is the only survey to provide a household-level income panel over a similar time frame in Manila. The analysis includes data from 22,107 households that were interviewed in both 2008 and 2011.

3. Credit through Delayed Water Bill Payments

In Manila, households have poor access to credit. Small-scale loans mainly from money lenders and micro-finance groups are the most common forms of credit and charge high monthly interest rates of 9.5% on average.[9] In this environment, delaying water

[8] Households using connections alone tend to be larger and wealthier than households that share connections with other households according to previous research (Violette [2019]).

[9] According to the 2014 Consumer Finance Survey in Manila, 1% have credit cards, 3.8% have auto-loans, 0.5% have mortgages, and 12% have all-purpose loans, of which 61% are from money lenders and 15% are from micro-finance groups.

bill payments may provide a reliable, alternative source of credit because the water utility often tolerates high rates of delinquency before disconnecting water service and the utility is prohibited from charging any interest on outstanding balances.

Households often delay their water bills. Instead of paying each month, households make large, infrequent payments. Table 1 provides summary statistics on household consumption, billing, and payments. While the average bill is 668 PhP per month, payments average 897 PhP, occur in 71% of months, and leave households 58 days behind on their bills. Each month, the average household maintains 1,235 PhP in unpaid water bills and only 538 PhP in small-scale loans mainly from money lenders and micro-finance groups.[10] With average monthly incomes of 21,907 PhP, households spend around 3% of their income on water while unpaid water bills total around 5.5% of their income.[11]

Table 1. Summary Statistics per Household-Month

	Mean	Standard Deviation
Consumption (m3)	24	15
Bill	668	730
Unpaid Balance	1235	3412
Payment	897	1058
Payment Frequency	0.704	0.457
Disconnection Frequency	0.015	0.122
Income	21907	19841

Bill, Unpaid Balance, Payment, and Income are in PhP. Measures exclude months where households remain disconnected through the end of the sample period. Billing data include 33,166 households for 2,123,335 household-month observations. Income data include 22,107 households for 44,214 household-month observations. 45 PhP = 1 USD

The utility enforces payment by visiting households and disconnecting them if they do not immediately pay their bills.[12] While households often try to negotiate for additional time to pay their bills, 96% of households report having to pay within 30 days and the average grace period is only 13 days. As a result, only 25% of households re-

[10] According to the 2014 Consumer Finance Survey in Manila, 12% of households have small-scale loans. Average loan sizes equal 51,280 PhP with an average period of 9 months.
[11] For reference, 1 USD is worth around 45 PhP over this period.
[12] Disconnection typically involves placing a metal lock on the water meter that stops any flow.

port having "enough time" to make their payments, which may be in part due to poor credit access in Manila. While disconnected, households likely substitute to alternative water sources including sharing with neighbors, using from deepwells, or purchasing from local water vendors. In the 2012 wave of the water connection survey, 6.1% of households report having been disconnected for delinquency. The billing data find that even among households that remain connected at the end of the sample period, 1.5% of their months are spent temporarily disconnected on average. To reconnect, households must pay any outstanding bills as well as 200 PhP reconnection fee.

The utility must frequently enforce payments because the utility often cannot recover unpaid bills once households have permanently disconnected and left the utility's service area. 7.5% of households remain disconnected at the end of the sample who are defined as "permanently disconnected" households for the purpose of this analysis. 79% of these households leave large outstanding balances that are never repaid averaging 7,119 PhP, which is over 10 times the average water bill. The remaining 21% pay their full balances upon disconnecting possibly because they plan to move to another dwelling within the utility's service area. Since 0.13% of households permanently disconnect each month on average,[13] then the average household remains connected for around 32 years assuming a constant rate over time.[14] Therefore, unpaid outstanding balances average 18.5 PhP per household-month or 2.8% of water bills.

Due to scarce resources, the utility is unable to visit every delinquent household each month. Instead, the utility appears to use a strategy workers sweep periodically through neighborhoods of around 200 households warning all households and issuing disconnection orders to especially delinquent households.[15] Neighborhood sweeps may provide an efficient strategy given high transport costs in Manila. On average, households receive 0.4 disconnection orders over the course of the sample. 72% of disconnection orders result in immediate payment of outstanding bills while 28% result in disconnection within two months. For these disconnected households, 64% eventually reconnect in an average of 6.7 months. The remaining 36% remain disconnected for the sample period. Households that do not receive a disconnection order also increase

[13]The disconnection rate is calculated (1) for households that connect between 2007 and 2011, which covers the connection survey and (2) for disconnections occurring between Jan, 2012 and May, 2014 to ensure that any disconnections last for at least a year before the sample ends in June, 2015.

[14]This constant rate is consistent with a weak observed correlation between the permanent disconnection rate and calendar months of -0.0033.

[15]Neighborhoods refer to areas defined internally by the utility as "Meter Reading Units." The utility has adopted a decentralized organizational structure by assigning one worker to manage each meter reading unit.

their bill payments when nearby households receive disconnection orders as part of a neighborhood warning.[16] While data do not record occurrences of warnings, frequent disconnection orders suggest that warnings are common events. On average, neighborhoods experience at least one disconnection order in 58% of months and at least four disconnection orders in 23% of months. Disconnection orders appear to occur at uneven intervals, which suggests that the timing of neighborhood warnings may be difficult for households to predict with precision.

Households may also pay their water bills infrequently for other reasons aside from accessing low-cost credit. First, households may not be aware of the size or due date for each water bill. The utility addresses this problem by sending meter readers to record monthly consumption, deliver each bill in person, and educate households about their payment options. Second, households may experience time or hassle costs in making each payment, which may naturally lead households to pay infrequently. The utility reduces these costs by offering many different payment options.[17] Third, previous research has documented how negative opinions toward public utilities or local governments can increase delinquency [Szabó and Ujhelyi, 2015]. In Manila, the utility enjoys largely positive public opinion because the water utility in Manila represents a public-private partnership that has dramatically improved service since taking over from the previous government utility.[18]

Unlike these other reasons for delinquency, the credit mechanism predicts that households with volatile incomes may time their bill payments to smooth their consumption over time (Deaton [1991]). The following equation tests whether income changes are more correlated with bill payments than with consumption by using changes in the number of working household members as a proxy for income changes

$$\Delta Y_{ht} = \beta_0 + \beta_1 \,\Delta\text{Working Members}_{ht} + \beta_2 \,\Delta\text{Total Members}_{ht} + \varepsilon_{ht}$$

where $\Delta\textsc{Working Members}_{ht}$ is the change in the number of working household members and $\Delta\textsc{Total Members}_{ht}$ is the change in the total number of household members between each survey round, t, and for each household, h. ΔY_{ht} include three

[16] Appendix 8.2 also finds that households do not increase payments in response to warnings for nearby households in separate neighborhoods.

[17] 79% of households use small payment centers (mall kiosks, gas stations, convenience stores, etc.), 17% of households pay at local utility offices, and 3% of households pay over the phone, online, or via ATM kiosks according to the connection survey.

[18] The connection survey conducts an independent assessment of people's satisfaction with the utility finding that over 95% of households rate the utility as "good" or "very good" as opposed to "fair," "poor," or "very poor" in terms of overall service quality.

outcomes measured in terms of changes in PhP per household-month: (1) water consumption measured by the water bill, (2) water bill payments, as well as (3) monthly household income, which is measured in 2008 and 2011 in the household survey from Pasay City. Standard errors are clustered at the household-level.

Table 2. Water Bills and Household Composition

	(1) Δ Bill	(2) Δ Payment	(3) Δ Income
Δ Working Members	6.7	40.8[a]	4920.0[a]
	(8.3)	(15.4)	(132.4)
Δ Total Members	23.1[a]	1.8	1480.1[a]
	(5.8)	(10.4)	(72.1)
Mean	565.0	552.9	21,663.2
R^2	0.010	0.003	0.143
N	4,788	4,808	21,374

Outcomes are in PhP per month and household members are reported in the 2008-2012 connection survey. Standard errors are clustered by household. Income changes exclude top and bottom 1% outliers. 45 PhP = 1 USD [c] $p<0.10$,[b] $p<0.05$,[a] $p<0.01$

Column (1) of Table 2 finds a large statistically significant correlation between total household members and consumption as well as a small, statistically insignificant correlation between employed members and consumption. This finding suggests both that the number of household members is a key driver of water demand and that changes in household income have little impact on water consumption. Column (2) finds the opposite pattern for payments where employed members drive large increases in payments while total household members exhibit almost zero correlation. Column (3) finds that working household members correlated much more strongly with household income than the total number of household members. Comparing results from Column (2) and (3), estimates suggest that in response to income shocks, households spend almost one out of every 100 PhP on outstanding bills. These results provide suggestive evidence of consumption smoothing where households flexibly adjust their payment patterns in response to income shocks without changing their water consumption.

These descriptive patterns are robust to an alternative measure of income shocks. Appendix 8.4 links the age, education, and location of connection owners to average changes in earnings for people with the same demographics from Quarterly Labor Force Surveys. This exercise finds patterns consistent with consumption smoothing although the correlations have relatively small magnitudes likely due to substantial measurement error.

4. A Model of Borrowing, Saving, and Water Use

To quantify the implications of different billing policies for household welfare, I construct a simple model of household borrowing, saving, and water consumption decisions over time. This approach builds on a standard buffer-stock savings model as developed by Deaton [1991].

4.1. Model Intuition

In this model, households first move to a dwelling in Manila and begin consuming piped water. As households receive positive income shocks, they accumulate precautionary savings to insure against future negative income shocks. In these months, households simply consume water according to their preferences and pay their bills.

When households receive enough negative income shocks, they spend their savings and begin to borrow. First, households borrow by not paying their water bills because they face zero interest rates on unpaid bills. Each successive month, households can increase this debt by continuing to consume water without paying.

Further negative income shocks may induce households to borrow beyond their current water bill at which point they face a trade-off: borrowing from a standard asset at a high interest rate or further increasing their water consumption to expand the size of their unpaid bills. For example, instead of taking out a costly loan from a moneylender, households may choose to wash clothes at home instead of at a laundromat or drink water instead of other beverages while leaving their bills unpaid. As substitution toward piped water becomes increasingly costly, households may then borrow from the standard asset.

With some probability, the utility conducts delinquency warnings, which confront indebted households with a choice: pay their debts or disconnect and use an alternative water source. Since the alternative water source involves an additional fixed cost each month, households with small debts may simply prefer to stay connected and pay their debts by taking out a costly loan and/or lowering their consumption this month. Households with large debts decide to disconnect in order to avoid taking out a large loan or experiencing a sharp drop in consumption this month. Once disconnected, households begin accumulating savings to eventually pay their debts and reconnect to service.

At some point, households learn whether they will move to a new dwelling in Manila or leave Manila. Households that plan to stay in Manila must pay their full balance before moving because it is likely that the utility will recognize them at their new address. Households that plan to leave Manila do not need to bay their outstanding debts before leaving. Therefore just before changing dwellings, these households have an incentive to accumulate large unpaid bills since the utility is unable to collect on these bills if households leave Manila. In these months, households may also have a strong incentive to disconnect in response to delinquency warnings.

4.2. Formal Model

To formally model household borrowing and savings decisions, I start from a standard intertemporal utility maximization problem as developed by Deaton [1991]. This approach assumes a finite time horizon where households choose water usage, borrowing, and savings in each month to maximize current and expected future utility.

Households first move to their dwelling in Manila in month 1 and then choose their consumption of water and other goods as well as how much to borrow and save each month until they leave their dwelling in month T. Household expected utility in each month t is given by the following equation

$$\begin{gathered} E_t\Big[\sum_{\tau=t}^{T}(1+\delta)^{t-\tau}\,\frac{u(w_\tau,x_\tau)^{1-\gamma}}{1-\gamma}\Big] \\ u(w_\tau,x_\tau) = x_\tau - \frac{1}{2}(w_\tau-\alpha)^2 \end{gathered} \tag{1}$$

where households have a rate of time preference $\delta \in (0,1)$. Households have quadratic preferences over water consumption, w_t, and a bundle of other goods, x_t. α is household's water satiation point each month, capturing the intuition that households are likely to consume a finite amount of water even if the price is zero.[19] Quadratic preferences also assume that income has no direct effect on consumption.[20] Households are assumed to have constant relative risk aversion for consumption across months given by γ.

[19]This approach assumes that households are unable to resell water from their tap.

[20]This assumption is consistent with descriptive evidence that fluctuations in household employment are uncorrelated with water spending.

In each month, households face a budget constraint as follows

$$x_t + pw_t = y_t - (1 - C_{t+1})f + A_t - \frac{A_{t+1}}{1+r} + B_t - B_{t+1} \tag{2}$$

where p captures the price of water, which is assumed to depend linearly on water consumption to approximate the tariff in Manila, $p = p_1 + p_2 w_t$. The price of the bundle of other goods, x_t, is normalized to one. y_t represents household income each month which takes a value of $(1+\theta)\bar{y}$ with probability π and a value of $(1-\theta)\bar{y}$ with probability $(1-\pi)$ where $\pi \in (0,1)$ and $\theta \in (0,1)$.

Households choose whether to remain connected in the next month given by C_{t+1}. When households are disconnected ($C_{t+1} = 0$), they are assumed to face an fixed cost f each month for water from alternative sources.[21] Since temporarily disconnected households are likely to share with neighbors or purchase from local vendors who resell piped water, they are assumed to face the same marginal prices as connected households.

Households can use asset, A, for borrowing and saving. A_t captures debt (when $A_t < 0$) or savings (when $A_t > 0$) inherited from the previous month. A_{t+1} captures how much debt or savings to pass onto the following month. Households are assumed to earn zero interest from saving consistent with low access to interest-bearing bank accounts in Manila.[22] Households face interest rate r_h when borrowing so that $r = r_h$ if $A_{t+1} < 0$ (and $r = 0$ if $A_{t+1} \geq 0$). Households are assumed to pay all debts or enjoy all savings from this asset before leaving Manila so that $A_T = 0$. Households are also assumed to face a borrowing constraint such that $A_{t+1} \geq \overline{A}$, which prevents households from infinitely borrowing.

Households can also borrow by delaying payments to their water bills. B_t (≤ 0) captures unpaid bills inherited from the previous month. B_{t+1} (≤ 0) describes how much water debt to pass onto the following month (by delaying payment of the current bill). Households must satisfy the following borrowing constraint each month, which ensures that water debt must be less than this month's bill and unpaid bills

[21] In practice, the utility may also charge monthly fixed prices. The model implicitly normalizes any utility fixed prices to zero, in which case the fixed cost of alternative water sources can be interpreted as a relative fixed price.

[22] Among households in the 2014 Consumer Finance Survey, 21% have bank accounts, 14% have bank accounts that pay interest, and 6% have accounts that pay interest and balances over 10,000 PhP, which is the minimum balance needed to earn interest. The Philippines National Bank lists an interest rate of 0.1% on savings accounts above 10,000 PhP (accessed Jan. 28th, 2020).

from previous months

$$B_{t+1} \geq (1 - v_t)C_t C_{t+1}(B_t - pw_t) + (1 - C_{t+1})B_t \geq \overline{B} \tag{3}$$

The choice of B_{t+1} depends on whether households receive a delinquency warning, v_t, which occurs with probability $\lambda \in (0, 1)$ and is assumed to be independent of the two income states. The choice of B_{t+1} also depends on whether households are connected to piped water, C_t, and choose to remain connected in the next month, C_{t+1}.

The borrowing constraint creates the following four cases:

Case 1: If there is no delinquency warning ($v_t = 0$) and the household is connected ($C_t = 1$) and chooses to stay connected ($C_{t+1} = 1$), then the household can borrow up to their existing water debt plus their bill this month so that the borrowing constraint equals $B_{t+1} \geq B_t - pw_t$.[23]

Case 2: If there is a delinquency warning ($v_t = 1$) and the household is connected ($C_t = 1$) and chooses to stay connected ($C_{t+1} = 1$), then the household needs to pay their existing debt and cannot borrow from their water bill this month so that $B_{t+1} = 0$.

Case 3: If the household chooses to be disconnected in the next month ($C_{t+1} = 0$) likely in response to a delinquency warning, then the household avoids paying the existing debt but faces an additional fixed cost of f per month to use a temporary water source. In this case, the borrowing constraint reduces to $B_{t+1} \geq B_t$ ensuring that households can only borrow up to their existing water debt.

Case 4: If the household is disconnected ($C_t = 0$) and chooses to reconnect ($C_{t+1} = 1$), then the household needs to pay off their existing debt and cannot borrow from their water bill this month so that $B_{t+1} = 0$.

Households also face an additional borrowing constraint, $B_{t+1} \geq \overline{B}$, which prevents households from borrowing indefinitely.

In the month $\overline{T}$, households learn where they will move at time T. With probability χ, households learn that they will move to a new home in Manila at time T in which case the need to pay their outstanding bills before moving (ie. $B_T = 0$). With probability $(1 - \chi)$, they will leave Manila at time T in which case they can leave bills unpaid with no consequence (ie. $0 \geq B_T \geq \overline{B}$).

The household's maximization problem can then be written recursively where households solve for a value function, $V_t(.)$, over four possible independent states given by s_t: (1) high income and delinquency warning with probability $\pi\lambda$, (2) high income and

[23]Borrowing is given by negative values for B_t and B_{t+1}

no delinquency warning with probability $\pi(1-\lambda)$, (3) low income and delinquency warning with probability $(1-\pi)\lambda$, and (4) low income and no delinquency warning with probability $(1-\pi)(1-\lambda)$. Given these states, the recursive problem can be written as follows

$$\begin{aligned} V_t(X_t, s_t) &= max_{w_t,x_t} \; \frac{u(w_\tau, x_\tau)^{1-\gamma}}{1-\gamma} + (1+\delta)^{-1} E\Big[\, V(X_{t+1}, s_{t+1})\Big] \\ X_t &= [w_t, x_t, A_{t+1}, B_{t+1}, C_{t+1}] \end{aligned} \tag{4}$$

with equations (2) and (3) holding each month.[24] This problem can be solved in two steps:

Step 1: For each possible choice of assets, A_{t+1} and B_{t+1}, and connection status, C_{t+1}, households maximize utility over water, w_t, and other goods, x_t, subject to their budget constraint and borrowing constraint. Within each month, households maximize utility given by $x_t - \frac{1}{2}(w_t - \alpha)^2$ such that the budget constraint and borrowing constraint hold. When the borrowing constraint does not bind, then households reach an interior solution given by $w_t^* = \frac{\alpha - p_1}{2p_2+1}$. The borrowing constraint does not bind when connected households have small unpaid bills (ie. B_{t+1} is small). Households also consume w_t^* in months where w_t does not affect the borrowing constraint such as when households are disconnected or when households receive delinquency warnings.

When connected households want to use large unpaid bills as a source of credit (ie. B_{t+1} is very negative), then the interior solution, w_t^*, may be too small to satisfy the borrowing constraint. Let $\overline{w}_t$ denote water consumption that just satisfies the borrowing constraint so that the bill this month, $-(p_1 + p_2\overline{w}_t)\overline{w}_t$ equals demand for additional borrowing, $B_{t+1} - B_t$ which gives $\overline{w}_t = \frac{(p_1^2 - 4p_2(B_{t+1}-B_t))^{.5} - p_1}{2p_2}$. When $w_t^* = \overline{w}_t$, the interior solution just satisfies the borrowing constraint. When $w_t^* < \overline{w}_t$, the interior solution is unable to satisfy the borrowing constraint so households consume $\overline{w}_t$. When $w_t^* > \overline{w}_t$, the interior solution more than satisfies the constraint so households consume w_t^*.

Step 2: Given optimal consumption choices of w_t and x_t, households then choose their assets and whether to remain connected each month to maximize $V_t(.)$. $V_t(.)$ can be solved by working backwards from month T where $A_T = 0$. Since households are assumed to have positive time preferences ($\delta > 0$) and zero interest on their savings, households have an incentive to consume their initial assets until they reach their borrowing constraints (Deaton [1991]).

[24] At time $\overline{T}$, households learn about whether they will move *in* or *out* of Manila at time, T, meaning that $E\Big[\, V(X_{t+1}, s_{t+1})\Big] = \chi E\Big[\, V_{in}(X_{t+1}, s_{t+1})\Big] + (1-\chi)E\Big[V_{out}(X_{t+1}, s_{t+1})\Big]$.

5. Estimation

Quantifying the welfare consequences of different billing policies requires estimates of household preferences for water consumption, the relative cost of an alternative water source, and the rate at which households receive delinquency warnings since neighborhood warnings of delinquent households are unobserved in the data.[25] The empirical strategy matches simulated consumption and payment patterns for a representative household to average patterns observed in the billing data. This strategy estimates the preference for water α from observed water consumption. The rate of delinquency warnings λ are estimated from the level of observed unpaid water bills since the frequency of delinquency warnings affects the incentive for households to accumulate unpaid water bills. The fixed cost of using an alternative water source each month f is identified by the observed share of households that temporarily disconnect in response to delinquency warnings.

5.1. Calibrated and Assumed Parameters

The empirical strategy requires calibrating prices, income, and interest rates to match economic conditions for the average household in Manila. The strategy uses a fixed price per m^3 of p_1 = 17.5 PhP and a marginal increase in price per m^3 of p_2 = 0.29 PhP, which together reflect the linear function that best fits the increasing tariff in Manila as shown in Appendix Table 9.[26] This approximation captures how prices increase with usage while also allowing for computational tractability within the dynamic model.[27]

Mean monthly income, $\overline{y}$, is calibrated to average income in the household panel survey of Pasay City, taking a value of 21,907 PhP. Monthly variation in income, θ, is calculated by dividing the standard deviation of household income net of household fixed effects by mean income for a value of 0.52.[28] For θ to capture monthly income variation within households, this calibration requires the assumption that reported income changes between 2008 and 2011 are representative of monthly income changes for households. This estimate for θ falls within range of previous estimates in the literature.[29] Households are also assumed to face even probabilities of high or low income

[25] The data only record disconnection orders.

[26] Appendix 8.3 includes more details on this calculation.

[27] Violette [2019] and Szabó [2015] carefully capture non-linear pricing incentives with static models, which are computationally expensive. The linear approximation also parallels average pricing models of consumer demand for utilities as suggested by Ito [2014].

[28] Household fixed effects are calculated using the 2008 and 2011 waves of the Pasay City survey.

[29] θ can also be interpreted as measuring the coefficient of variation (CV), which measures the stan-

realizations each month, which implies that π equals 0.5. The monthly interest rate on borrowing from standard assets is calibrated to equal 9.5% according to reported rates for "all-purpose" loans from the Consumer Finance Survey for Metro Manila. The majority of these loans are issued from money lenders.

The estimation also assumes parameters for household time-preferences. First, the monthly discount rate δ is assumed to equal 0.005, which implies an annual discount rate of around 6%. This discount rate is in range of estimates from similar structural dynamic models.[30] Second, the coefficient of relative risk aversion γ is set equal to 1, which is approximated by the natural logarithm and falls within a wide range of estimates from the literature.[31] Estimates are also provided under alternative preference assumptions.

Households are assumed to remain at their dwelling for $T = 384$ months before disconnecting, consistent with a 0.13% rate of permanent disconnection each month as observed in the sample. Upon disconnection, 21% of households pay all of their remaining balances, which calibrates the share χ of households that are assumed to move to a new dwelling within Manila. Moreover, 12 months before disconnection, households are assumed to learn if they will have to pay their remaining balances upon disconnection. This assumption is consistent with households accelerating their unpaid balances starting 12 months before disconnection.[32]

5.2. Estimation Routine

The estimation routine solves the household's problem in equation (4) through backwards induction. In the last month $T = 384$, the routine finds the combination of water and asset choices that maximize utility in both the scenario where households must pay back their standard and water debts as well as the scenario where households do

dard deviation of monthly household income divided by average household income (Hannagan and Morduch [2015]). Hannagan and Morduch [2015] use monthly financial diaries in the US to calculate CVs of 0.39 for average households and 0.55 for households below the poverty line. Using household surveys from Mexico, Amuedo-Dorantes and Pozo [2011] calculate CVs between 0.29 and 0.46.

[30]In US contexts,Gourinchas and Parker [2002] use a similar structural approach finding a lower discount rate of around 5% while Laibson et al. [2007] recover a discount rate of around 15%.

[31]The literature provides a range of estimates for γ which are above, below, and around one. Barseghyan et al. [2013] use insurance choices in the US to estimate a γ between 0.21 and 0.37 while Beetsma and Schotman [2001] use a natural experiment from a game show to estimate γ ranging from 0.42 to 6.99. Carvalho et al. [2016] leverage an experimental setting in Nepal to estimate ρ equal to 0.63. Given these estimates, assuming ρ equal to one implies a moderate curvature of the utility function and is relatively close to a comparable estimate from a development economics setting.

[32]Figure 1 in Appendix **??** plots average unpaid balances in the 36 months before permanent disconnection, finding an increasing trend that accelerates within 12 months of disconnection.

not have to pay back their water debt. Taking these choices as given, the routine then steps back to month $T-1$ and finds the combination of assets and connection status that maximizes current utility plus discounted future utility separately for both scenarios. In the thirteenth month before disconnection, households do not know whether they will have to pay back their water debt in month T. Therefore, their total expected future utility weighs expected future utilities under each scenario by their probabilities of occurring. Repeating this process for earlier months brings households to a steady state mapping of current assets and connection status to future assets and connection status.

The routine allows households to choose across 40 standard asset values and 40 water asset values.[33] Standard assets values are evenly spaced between borrowing and saving up to twice average household income. In simulations, households are never observed borrowing the maximum amount and are observed saving the maximum amount in less than 1% of months. Water assets are evenly spaced between 0 and borrowing up to 16,082 PhP, which is equal to the 99th percentile of observed water debt. In simulations, households are observed borrowing the maximum amount of water debt in less than 0.1% of months.[34]

The estimation strategy uses a simulated method of moments approach. This method begins with an initial guess of values for the water preference, the fixed cost of being disconnected, and the probability of receiving a disconnection warning. The method then computes the optimal path of asset choices and consumption given these parameters. Next, the method takes 384 month random sequences of income and disconnection warning states and computes the savings and consumption profiles for 50 households. Finally, the method computes three moments – average consumption, average unpaid water bills, and average time spent temporarily disconnected – for these simulated profiles and compares these simulated moments to moments observed in the data. The method repeats this process updating the initial parameter guesses in order to minimize the sum of squared distances between simulated and true moments.[35]

5.3. Results

Table 3 provides the estimation results. Household preference for water is estimated to be 54. Given quadratic preferences for water consumption, this parameter can be

[33] Estimates are similar using denser grids with results available upon request.
[34] For reference, Appendix Table 12 lists the calibrated and assumed parameters.
[35] See Laibson et al. [2007] and Gourinchas and Parker [2002] for similar approaches to estimation with dynamic consumption and savings models.

interpreted as optimal household consumption when the marginal price of water is zero. This estimate suggests that households would roughly double their water consumption if water were free. The estimation recovers a fixed cost of being disconnected of 327 PhP per month. Given average water bills of 668 PhP, this fixed cost estimate implies that households must pay around a 50% total premium to consume from alternative water sources. This estimate is also likely to capture the one-time 200 PhP fee charged to households for reconnection. The share of months that households receive delinquency warnings is estimated to be 0.22. This estimate closely matches descriptive evidence that neighborhoods experience at least four disconnection orders in 23% of months. Estimates appear robust to alternative assumptions for household time-preferences.[36]

Table 3. Estimates

Water Preference (α)	54.0
	(0.00)
Fixed Cost of Alternative Water (f)	326.5
	(0.0)
Rate of Delinquency Warnings (λ)	0.22
	(0.00)
Households	33,166
Household-Months	2,021,144

Standard errors in parentheses are bootstrapped at the household-level.

Table 4 provides average characteristics observed in the data and predicted by the estimated model. The table also includes both average characteristics used for estimation (shaded in gray) as well as other average characteristics to help understand the fit of the model. Since the model is exactly identified, the model is able to almost exactly predict the average characteristics used in estimation – consumption, unpaid balance, and disconnection frequency.

In terms of characteristics that are not used in estimation, both the data and the model predict that household bill payments occur infrequently and are large relative to average bills.[37] In both, households remain temporarily disconnected for long dura-

[36] Appendix Table 14 provides estimates under high and low discount rates and levels of risk aversion.

[37] The model slightly underestimates the average water bill for households likely because the model approximates the steeply increasing tariff structure with a linear function that cannot capture how

tions before reconnecting to service. The model and data also predict similar levels of unpaid bills when households permanently disconnect, which suggests that the model may accurately capture the lost revenue associated with household delinquency.

Table 4. Model Fit to Average Characteristics

	Data	Model Prediction
Consumption (m3)	24	24
Bill	668	597
Unpaid Balance	1235	1231
Payment	897	676
Payment Frequency	0.704	0.883
Disconnection Frequency	0.015	0.015
Disconnection Length (Months)	6.7	2.7
Unpaid Balance Upon Permanent Disconnection	7923	7620

The highlighted cells indicate the three moments used in estimation. Measures exclude months where households remain disconnected through the end of the sample period. 45 PhP = 1 USD

The model predicts that households make more frequent, smaller payments and spend relatively shorter durations temporarily disconnected than those observed in the data. One explanation may be that households experience persistent income shocks while the simple income process in the model assumes zero persistence. Persistent income shocks may lead households to make lumpy payments during positive income realizations and remain disconnected for long durations during negative income realizations. By assuming zero income persistence, the model may underestimate the value to households of timing bill payments to smooth their consumption.

Appendix Table 13 provides the corresponding standard deviations for these characteristics both observed in the data and predicted by the estimated model. The model grossly underestimates variation in consumption since the model only allows consumption to vary when households substitute toward water to increase their borrowing through unpaid bills. The model does not allow for idiosyncratic fluctuations in

months with large consumption result in especially large bills.

water demand. Despite this simplification, the model accounts for nearly two-thirds of the observed variation unpaid balances and almost exactly matches variation in payment sizes. These findings suggest that while the model may not accurately predict fluctuations in water demand, it may provide a useful approximation for consumption smoothing over time.

The model also predicts a positive correlation between income and bill payments of 0.10, which is 10 times larger than the correlation implied by descriptive evidence in Table 2. The model may overestimate the relationship between payments and income because the model does not account for hassle costs or other factors that may affect payment patterns independently of income fluctuations. At the same time, descriptive evidence likely underestimates this relationship due to substantial measurement error in accounting for household income changes.

The model predicts a negative correlation between income and consumption of -0.17. By contrast, descriptive evidence in Table 2 predicts close to zero correlation between income and consumption. By ignoring idiosyncratic water demand shocks, the model isolates only the consumption changes that occur when households substitute toward water consumption in order to borrow further through unpaid water bills.

6. Counterfactual Policies

The estimated model allows for simulating the welfare effects of counterfactual billing policies. The first counterfactual implements a prepaid metering system that requires households to pay upfront for their water consumption. This system prevents households from timing their bill payments to smooth their consumption. The second counterfactual halves the frequency of disconnection warnings. This policy encourages households to accumulate large unpaid bills and smooth their consumption.

These policies are paired with price adjustments that ensure that the utility's revenues always equal its costs. This revenue-neutral approach reflects how governments in Manila and many other countries regulate utility prices (Hoque and Wichelns [2013]). Since utility profits are held constant at zero, changes in household welfare summarize the total welfare effects of the counterfactual policies.

6.1. Modeling Utility Costs and Revenues

The counterfactual exercises account for how policies may affect utility operating costs in three ways:

1. *Lending Costs*: By tolerating unpaid bills, the utility extends credit to households each month at zero interest rate. The opportunity cost of this credit is equal to the 0.47% monthly interest rate that the utility pays on its own loans to fund its pipe infrastructure.[38] These opportunity costs average 6 PhP per household-month. The utility also loses revenue from households that leave unpaid bills when they disconnect, which average 20 PhP per household-month. Total lending opportunity costs per household can be expressed as $-\chi B_T + \sum_{t=1}^{T} -0.0047 B_t$ where B_t (< 0) equals unpaid bills each month and χ is the share of households that leave unpaid bills upon disconnection.

2. *Warning Costs*: The utility incurs costs visiting and warning each delinquent household about their unpaid bills. The cost of administering each warning is assumed to equal the reconnection fee of 200 PhP, which leads to average warning costs of 29 PhP per household-month.[39] Total warning costs per household can be expressed as $\sum_{t=1}^{T} 200\lambda \mathbb{1}\{B_t < 0\}$ where $\mathbb{1}\{B_t < 0\}$ indicates months where households are delinquent and λ indicates the share of months where the utility conducts warnings.

3. *Pumping Costs*: The utility estimates that the marginal cost of supplying a cubic meter of water is equal to 5 PhP, which generates average marginal costs of 121 PhP per household-month. Total marginal costs per household can be expressed as $\sum_{t=1}^{T} 5w_t$ where w_t reflects monthly water consumption.

Under Manila's price regulations, total revenue net of operating costs equal the fixed costs of building and maintaining the pipe network. Therefore, fixed costs are measured as observed revenue net of observed operating costs according to the following equation

$$\sum_{t=1}^{T} FC = \underbrace{\sum_{t=1}^{T} (p_1 + p_2 w_t) w_t}_{\text{Revenue}} - \underbrace{\Big[-\chi B_T + \sum_{t=1}^{T} 5w_t + 200\lambda \mathbb{1}\{B_t < 0\} - 0.0047 B_t \Big]}_{\text{Operating Costs}} \tag{5}$$

where FC equals fixed costs in monthly terms and averages 421 PhP per household-month. Fixed costs are assumed to remain constant in counterfactual simulations. As each counterfactual policy changes household consumption and billing patterns, the

[38] The 0.47% monthly interest rate is equal to a 5.75% annual interest rate.

[39] Conversations with the utility suggest that travel costs make up the majority of the costs for any service performed on a water meter.

simulation adjusts the marginal price per cubic meter, p_1, to satisfy equation (5). For each counterfactual policy, Table 5 provides simulated cost and price changes, and Table 6 provides simulated household outcomes.

6.2. Prepaid Metering

Prepaid metering generates cost savings because with prepaid meters, the utility no longer needs to conduct delinquency warnings and households can no longer leave their bills unpaid. These costs savings lead to a reduction in the water price needed to cover the remaining pumping and fixed costs. Column (2) of Table 5 summarizes these cost changes under prepaid metering, finding a substantial reduction in the marginal price per m3 from 17.6 to 14.8. This reduction brings marginal prices closer to the marginal pumping cost of 5 PhP per m3, leading households to consume greater and more efficient quantities of water.

Table 5. Costs under Counterfactual Policies

	(1) Current	(2) Prepaid Metering	(3) 50% Less Enforcement
Lending Costs	26	0	44
Warning Costs	29	0	18
Pumping Costs	121	124	128
Fixed Cost	421	421	421
Price per m3	17.6	14.8	16.3

All cost and bill measures are in PhP per household-month. 45 PhP = 1 USD

Despite the decrease in prices, the exercise predicts that prepaid metering lowers social welfare. The first row of Table 6 calculates the compensating variation associated with each policy, which measures the change in monthly household income needed to make households indifferent between the current scenario in Manila and each policy. Column (2) predicts that households would require an increase in their monthly incomes of at least 40 PhP in order to be willing to switch to prepaid metering. This decline in welfare appears entirely driven by removing households' ability to smooth consumption through unpaid bills. Comparing columns (1) and (2), unpaid balances drop from 1,235 to 0 PhP and standard borrowing levels drop by around 80 PhP. These findings suggest that households substantially reduce their overall borrowing levels when credit from unpaid bills is no longer available.

Table 6. Household Outcomes under Counterfactual Policies

	(1) Current	(2) Prepaid Metering	(3) 50% Less Enforcement
Compensating Variation		40	-117
Consumption (m3)	24.2	24.8	25.7
Bill	597	546	613
Unpaid Balance	1235	0	3199
Standard Borrowing	765	688	710

Compensating variation measures the change in monthly income needed to make households indifferent between the current scenario and the counterfactual scenario. All measures are per household-month. Bill and outstanding balance are measured monthly in PhP. Price per m3 reflects the constant marginal price per m3, p_1, so that total price equals $p_1 + p_2 w_t$ where w_t is monthly consumption in m3. 45 PhP = 1 USD

This exercise assumes that the utility faces negligible costs of installing and maintaining prepaid meters. However as detailed in Appendix 8.5, engineering estimates from 2014 suggest that prepaid meters may cost up to 51 PhP more per household-month than current meters. While prepaid metering costs may likely decline with future technological innovation, these costs suggest that this counterfactual exercise underestimates the welfare costs from prepaid metering.

This exercise adjusts the marginal water price to ensure that revenues equal costs. Alternatively, the utility may issue fixed rebates to consumers while holding marginal prices constant. Under fixed rebates, prepaid metering would generate larger welfare losses because any cost savings would be directly transfered to households instead of helping to bring marginal prices closer to marginal costs. It is unlikely that a system of fixed rebates would occur in this setting given that most tariff adjustments target marginal rates.

The negative welfare effects of prepaid metering appear robust to alternative assumptions on household preferences. Appendix Table 14 provides the compensating variation associated with prepaid metering under high and low discount rates and levels of risk aversion. High discount rates and levels of risk aversion both increase household demand for consumption smoothing, which magnify the welfare costs of prepaid metering. Welfare losses from prepaid metering are also higher under low estimated water preferences because households derive less utility from the price discounts brought by prepaid metering. Estimates suggest uniformly negative welfare impacts impacts ranging from 5 to 113 PhP.

6.3. 50% Less Enforcement

The next counterfactual considers a 50% reduction in delinquency enforcement, which is modeled by lowering the monthly probability of receiving a delinquency warning from 22% to 11%. The exercise predicts that a 50% reduction in delinquency enforcement substantially increases social welfare. Compensating variation in Column (3) of Table 6 indicates that households would tolerate a decrease in their monthly incomes of up to 117 PhP and still be willing to switch to a counterfactual with 50% less delinquency enforcement.

This welfare gain comes from two channels. First, less enforcement decreases the costs to households of using unpaid water bills as a source of credit. Comparing columns (1) and (3) of Table 6, households almost triple their average unpaid balances while also reducing borrowing from standard assets. Second, less enforcement leads households to increase their water consumption in order to have large unpaid bills as a source of credit. Greater water consumption increases utility revenue net of pumping costs. On net, Column (3) of Table 5 indicates that the utility is able to cover its costs at a lower marginal price of 16.3 PhP, which also improves household welfare. This price lies midway between the current price (column (1)) and the price with prepaid metering (column (2)).

This exercise does not allow for the possibility that with less delinquency enforcement, some households may choose to connect to piped water, quickly accumulate large unpaid bills, and permanently disconnect as soon as they receive a warning. Without accounting for these costly disconnections, the counterfactual exercise may underestimate the lending costs from lowering enforcement and therefore, may overestimate the welfare benefits to households.

The positive welfare effects of reducing enforcement appear robust to alternative assumptions on household preferences. Appendix Table 14 provides the compensating variation of reducing delinquency enforcement under high and low discount rates and levels of risk aversion. High discount rates and levels of risk aversion both increase household demand for consumption smoothing, which magnify the welfare benefits of reduced enforcement. Estimates suggest uniformly positive welfare impacts impacts ranging from 94 to 161 PhP.

7. Conclusion

Policy proposals for prepaid meters often emphasize how this technology ensures cost-recovery for utility providers. At the same time, households stress how "water is a need, but money is not always available" and how "postpaid gives you more time to find the money" in qualitative evidence documented by Heymans et al. [2014]. These anecdotes suggest a potentially important role for billing flexibility in allowing households to smooth consumption. This paper confirms this hypothesis by building and estimating a dynamic model of household consumption smoothing. While prepaid meters reduce welfare, expanding access to credit through unpaid bills generates economically significant welfare gains on the order of 18% of average water bills.

These results may open scope for regulating public utilities not only as service providers, but also as lenders. When market failures limit formal lending, public utilities may provide efficient sources of credit. First, poor access to collateral often restricts the availability of lending options to low-income households (Jack et al. [2016]). Public utilities overcome this barrier by threatening disconnection from future service to enforce repayment. Second, poor infrastructure and mobile populations increase the transaction costs of screening and monitoring debtors, which contribute to high interest rates (Jack and Suri [2014]). As part of their business practices, public utilities invest in meter reading and billing systems that may lower these transaction costs. Third, moneylenders and peer-to-peer lending groups often cater to small pools of debtors while public utilities are able to spread default risk across a wide customer base. To this encourage lending, regulators may want to consider a broader set of policies such as providing utilities with tools to track delinquent households over time and space or allowing utilities to offer loans that are not strictly linked to the household's consumption of services.

In focusing on the role of consumption smoothing, this approach abstracts away from other channels by which nonpayment may affect welfare. First, high rates of nonpayment may weaken incentives for utilities to invest in and extend access to high quality infrastructure. While regulators in Manila successfully ensure universal access and service quality, McRae [2015] documents how electricity providers in Colombia often shirk on infrastructure investments in areas where they face high levels of nonpayment, which are also often underprivileged areas. Second, policing nonpayment through unexpected disconnections may also have unintended health consequences (Franklin and Kurtz [2017]). The US Department of Health and Human Services [2019] lists a series of state-level policies restricting disconnections, especially in months with extreme temperatures, for public health reasons. Finally, nonpayment may provide an important way for households to voice their dissatisfaction with a utility as well as local government. Szabó and Ujhelyi [2015] find evidence that reaching out to consumers on behalf of a water utility increased payments from households motivated by a sense of reciprocity.

8. Appendix

8.1. Sample Construction

Merging the full sample from the connection survey to the billing data yields an initial population of 4,678,420 connection-months as described in Table 7. Non-residential accounts are first removed to ensure that results apply to household-level decisions. Due to some data inconsistencies, payment records are missing for some connections, which are excluded. Due to leaks, meter replacements, and meter reading errors, connections occasionally experience extremely high meter readings and bills. Consumption records above 200 m3 as well as bills and payments above 80,000 are censored to address these issues. Large negative payments and outstanding balances (due to reimbursements of billing errors) are also excluded due to likely measurement error. Remaining negative payments and balances likely represent refunds to households (possibly due to system errors), which are included to accurately reflect each household's asset position. Keeping only connections serving single households removes nearly one million observations.

The descriptive panel analysis with results in Table 2 uses the dataset at this stage, which includes observations before March, 2010. These observations match connection survey data from as early as 2008 although billing data from the earlier period include some gaps in payment and consumption records.

The dataset for the main analysis focuses on months including and after March, 2010 because these months do not include gaps in payment and billing records (except that all data are missing for June, 2014). Excluding data before March, 2010 brings the final sample size to 2,872,815 household-months.

Table 7. Sample Construction

	Observations	Observations Removed
Initial sample	4,678,420	
Keep residential connections (excluding commercial)		632,903
Keep connections with payment records		40,708
Keep months with usage under 200 m3		73,219
Keep bills > -5,000 PhP and < 80,000 PhP		84,048
Keep unpaid bills > -5,000 PhP and < 80,000 PhP		12,087
Keep payments > -80,000 PhP and < 80,000 PhP		791
Keep connections serving a single household		961,849
Keep months after March, 2010 (with complete records)		1,813,520
Final sample	2,021,144	

8.2. Bill Payments and Delinquency Warnings

The following equation estimates the effect of delinquency warnings on bill payments

$$\begin{aligned}
Pay_{it} = \alpha + \beta\{\text{own warning}\}_{it} + \\
& \sum_{k=1}^{3} \gamma_k\{\text{warning for k-th nearest HH in same neighborhood}\}_{it} + \\
& \sum_{j=1}^{3} \theta_j\{\text{warning for j-th nearest HH in different neighborhood}\}_{it} + \eta_i + \zeta_t + \epsilon_{it}
\end{aligned}$$

where i indexes households and t indexes months. Pay indicates bill payments in the same month. Indicators variables signal months where households receive warnings and where their three immediate neighbors receive warnings. Immediate neighbors are considered separately based on whether neighbors reside in the same or different neighborhoods. The specification also includes household fixed effects (η_i) and calendar month fixed effects (ζ_t). Information on the exact location of each household is available for over half of the sample, which is used to measure distances between households.

Table 8 includes the results of this exercise. Receiving a delinquency warning is correlated with large, immediate increases in bill payments around the size of the average bill payment in the sample. Conditional on receiving a warning, households that have immediate neighbors who receive warnings in the same neighborhood also increase their bill payments although the magnitudes are much smaller than the own warning effect. Warnings for the 3rd nearest household have a slightly smaller effect than warnings for the nearest household although warnings for all households are positive and significant. Households do not appear to change their payment behavior when nearby households in different neighborhoods receive warnings, which suggests that the utility follows a neighborhood sweeping strategy.

Table 8. Bill Payments and Delinquency Warnings

	Bill Payment (PhP)
Own Warning	587.51[a]
	(19.73)
Warning in Same Neighborhood for:	
1st Nearest Household	42.36[a]
	(11.67)
2nd Nearest Household	46.63[a]
	(11.06)
3rd Nearest Household	33.56[a]
	(11.67)
Warning in Different Neighborhood for:	
1st Nearest Household	10.97
	(33.01)
2nd Nearest Household	-6.11
	(28.85)
3rd Nearest Household	7.58
	(25.21)
Mean	629.40
R^2	0.286
N	1,148,439

Household and calendar-month fixed effects are included. Standard errors are clustered at the household level. [c] $p<0.10$,[b] $p<0.05$,[a] $p<0.01$

Figure 1. Average Unpaid Bills in 36 Months Before Permanent Disconnection

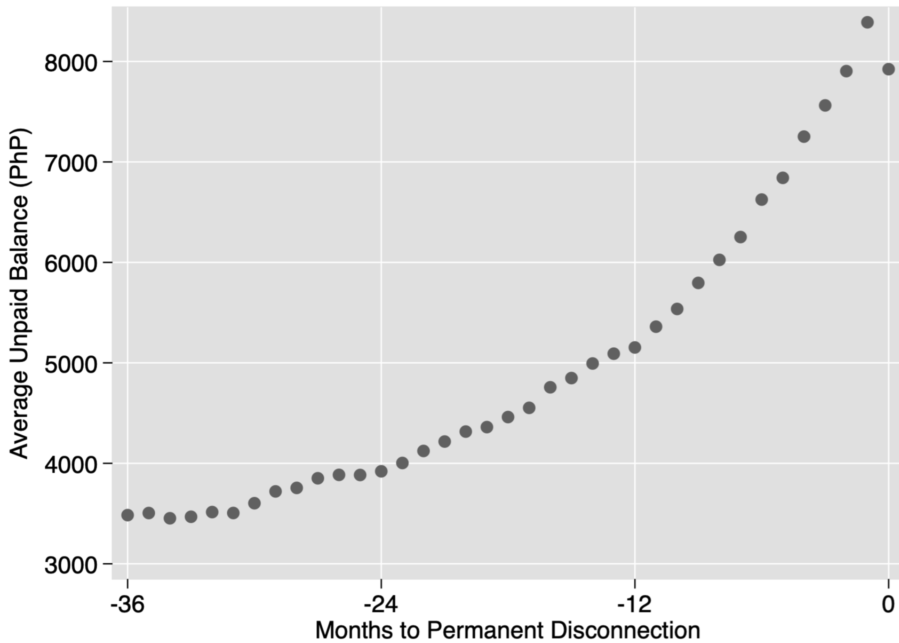

Table 9. Example Residential Tariff As Presented to Consumers

Usage (m3)	Price (PhP)
Under 10	104.79 /conn.
Over 10	181.31 /conn.
Next 10	19.20 /cu.m.
Next 20	25.52 /cu.m.
Next 20	33.94 /cu.m.
Next 20	40.73 /cu.m.
Next 20	45.99 /cu.m.
Next 50	50.88 /cu.m.
Next 50	55.53 /cu.m.
Over 200	57.86 /cu.m.

Mean tariff 2010-2015 with value added tax.
"conn." refers to connection.
"cu.m." refers to m3/month. 45 PhP = 1 USD

8.3. Tariff Structure and Approximation

Table 9 provides the monthly tariff structure as it is presented to consumers. Consumers face a fixed price as well as marginal prices for any usage above 10 m3. The regulator gradually adjusts prices at roughly yearly intervals in order to ensure that the utility is able to exactly cover its costs. The marginal price is highly non-linear, accelerating quickly at low usage levels before slowly increasing at high usage levels. To achieve a tractable approximation of this price schedule, Table 10 fits a simple regression model predicting average price as a function of an intercept, p_1, and monthly usage levels, p_2. This model predicts that a increase in monthly usage of 10 m3 results in an increase in average price of 2.2 PhP/m3.

Table 10. Average Price and Monthly Usage

	Avg. Price: $\frac{\text{Bill (PhP)}}{\text{Usage (m3)}}$
Usage (m3)	0.29[a]
	(0.00)
Intercept	17.57[a]
	(0.05)
Household-Months	1,861,200

[c] p<0.10,[b] p<0.05,[a] p<0.01

8.4. Alternative Income Test

The following equation empirically tests whether income is more correlated with bill payments than with consumption

$$\Delta Y_{bq} = \beta\, \Delta \text{INCOME}_{bq} + \gamma_q + \varepsilon_{bq}$$

where INCOME_{bq} is proxied by the quarterly change in average labor earnings from Quarterly Labor Force Surveys where q indexes 28 quarters from 2009 to 2015. Average earnings are computed for 80 unique bins, b, defined by combinations of 4 sub-municipalities, age in 5 year intervals, and whether college educated in order to merge individuals from the Labor Force Survey to individuals water connection owners from the water connection survey. ΔY_{bq} is the quarterly change in either average water consumption (measured by the water bill in PhP) or average water bill payments (in PhP) by bin-quarter. Standard errors are clustered at the bin-level.

Column (1) of Table 11 finds a positive but statistically insignificant correlation between income and consumption. Due to measurement error in income, the small point estimate of 0.0007 likely underestimates this correlation. Measurement error in income is likely to be substantial both because only around 55 incomes are observed per quarter-bin in the Labor Force Survey and because bins are constructed from coarse demographic categories that may only loosely reflect household incomes. Despite this potential measurement error, Column (2) finds a statistically significant correlation between bill payments and income that is six times larger than the correlation between income and consumption. These results provide suggestive evidence of consumption smoothing where households flexibly adjust their payment patterns in response to in-

Table 11. Correlations of Income with Consumption and Payment Patterns

	(1) Δ Consumption	(2) Δ Payment
Δ Income	0.0007	0.0042[a]
	(0.0011)	(0.0013)
Mean	651	640
R^2	0.451	0.154
N	1,516	1,516

All units are in PhP. Quarterly fixed effects are included. Standard errors are clustered by age-group, sub-municipality, and whether college educated (80 units). [c] $p<0.10$,[b] $p<0.05$,[a] $p<0.01$

come shocks without changing their water consumption.

Table 12. Calibrated and Assumed Parameters

Mean Income (PhP)	$\bar{y}$	21,907	Pasay City Household Panel Survey
Income Coefficient of Variation	θ	0.52	Pasay City Household Panel Survey
Interest Rate on Standard Borrowing	r	9.5%	Consumer Finance Survey for Manila
Tariff	$(p_1 + p_2 w)$	$(17.6 + 0.3w)$	Estimated price by water usage (See Appendix 8.3 for details)
Discount Rate	δ	0.5%	In range of structural estimates from literature[†]
Coefficient of Relative Risk Aversion	γ	1	In range of structural estimates from literature[⋄]
Standard Asset Range	A	{-43,814, 43,814}	Assumed to capture reasonable borrowing and saving constraints
Water Borrowing Range	B	{-16,082, 0}	Assumed to capture reasonable water borrowing constraints
Household Water Account Length	T	384	Implied by 0.13% of households disconnecting each month
Paying Balance upon Disconnection	χ	21 %	Directly observed in billing data
When Households learn about whether to pay balance upon disconnection	$\overline{T}$	$T - 12 = 372$	Payment patterns before disconnection

All measures are monthly. Annual rates are converted to monthly rates as follows: Monthly Rate = $(1 + \text{Annual Rate})^{1/12} - 1$

[†] See Andreoni and Sprenger [2012], Laibson et al. [2007], and Gourinchas and Parker [2002] for structural δ estimates.

[⋄] See Barseghyan et al. [2013], Beetsma and Schotman [2001], and Carvalho et al. [2016] for structural λ estimates.

Table 13. Model Fit to Standard Deviation of Characteristics

	Data	Model Prediction
Consumption (m3)	15	3
Bill	730	119
Unpaid Balance	3412	2010
Payment	1058	1073
Payment Frequency	0.457	0.322
Disconnection Frequency	0.122	0.122
Disconnection Length (Months)	7.7	2.2
Unpaid Balance Upon Permanent Disconnection	12643	5076

8.5. Cost Premium for Purchasing Prepaid Metering

Prepaid meters introduce an additional cost for the utility in terms of purchasing and installing this new technology. Heymans et al. [2014] surveyed eight large water providers that implemented prepaid meters in developing countries and found that each prepaid meter costs about four times as much as a standard meter and requires replacement every 7 years. In according to documentation from Manila, each standard meter costs around 1,500 PhP and is replaced around every 6 years and 3 months, bringing the monthly cost to 20 PhP/month. Assuming that a prepaid meter costs 4 times as much as a standard meter with a replacement rate of 7 years, the estimated monthly cost of a prepaid meter would be 71 PhP/month. Therefore, prepaid meters imply an additional cost of 51 PhP/month per household. Heymans et al. [2014] also report that the fixed administrative costs of installing and monitoring new meters account for less than 4% of the total costs of switching to prepaid meters while the bulk of the expenses come from purchasing new meters.

Table 14. Estimates under Alternative Preference Assumptions

	Current	High Rate	Low Rate	High CRRA	Low CRRA
Assumed Preferences					
Discount Rate (δ)	.005	.01	.0025	.005	.005
CRRA Curvature (γ)	1	1	1	2	.5
Estimates					
Water Preference	54.0	54.0	54.0	53.6	54.5
Fixed Cost of Alternative	326.5	375.8	332.5	382.5	283.0
Rate of Warnings	0.22	0.24	0.21	0.21	0.24
Compensating Variation					
Prepaid Metering	40	40	54	113	5
50% Less Enforcement	-117	-126	-112	-161	-94

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